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Abstract. Amid growing global environmental concerns, education plays a critical role in shaping students' understanding and attitudes toward sustainability. Science education, in particular, is uniquely positioned to foster environmental awareness and encourage responsible behaviors. This research was conducted to identify science teachers' perspectives regarding their role in instilling environmental sustainability values and reinforcing responsible behaviors among their students. A qualitative approach was employed through conducting interviews with a purposive convenience sample of 51 primary-stage science teachers in Saudi Arabia. Collected data was analyzed based on the grounded theory approach to facilitate the extraction of core ideas and themes. The findings demonstrated that teachers are deeply aware of their role in the reciprocal relation between human and the environment, which extends beyond knowledge transmission to shaping students' environmental behaviors, and that their environmental practices function as a model that strongly influences students' practices. Teachers' awareness of modeling, intellectual empowerment, and capability to link learning to real life situations demonstrated their deep understanding of how environmental education shapes long-term environmental attitudes. They highlighted empowering students to expect environmental challenges through integrating science curricula into real-life concerns. The findings strongly support integrating sustainability across disciplines to provide a comprehensive understanding of the concept and demonstrate science teachers' advanced educational vision to facilitate values and critical thinking rather than knowledge transmission.
Keywords: primary science education, environmental sustainability, teachers' beliefs, contextualized teaching

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TOWARDS AN ACTIVE ENVIRONMENTAL CITIZEN: SCIENCE EDUCATION AS A CATALYST FOR SUSTAINABILITY IN STUDENTS' THINKING AND BEHAVIOR

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Introduction

Since its beginnings, humanity has profoundly and permanently altered its environment on a planetary scale. The current environmental crisis is characterized by unprecedented complexity, as climate change is no longer the sole threat, but many interconnected factors have joined to collectively threaten the survival of life (Baptista et. al, 2025; Castro & Gómez Zermeño, 2020). Dangerous challenges have been experienced due to "Greenhouse Effect", resulting in global warming, droughts, floods, and glacial retreat, and causing economic and social instability (Menchaca-Torre et al, 2024; UNESCO, 2020). The combination of declined biodiversity as well as deteriorated air, water, and soil quality created a threatening situation for human health and quality of life (UNESCO 2017).

These environmental disruptions are not solely the product of natural occurrences; rather, they stem from the misguided development approaches based on the exploitation of resources and short-term economic benefits at the expense of ecological balance and the rights of future generations (Castro & Gómez Zermeño, 2020; Li & Shein, 2023). The exploitation of vulnerable and poor communities for the purposes of greater economic productivity worsens the situation. The poor are the most vulnerable to environmental deterioration despite being the least responsible for such degradation. Thus, a shift grounded in ecological justice, global interdependence, and sustainable principles that take into account the well-being of future generations is necessary (Al-Hassan et al., 2025).

In this regard, no longer can environmental problems only be dealt with by specialists or designated organizations. The problems today affect all human domains, which need political, economic, cultural, and educational solutions (Ghosh & Prasad, 2024; Hadjichambi et al., 2023). Education stands as the most transformative domain among all others because environmental education demonstrates the greatest potential for change. The world's urgent problems have eliminated education's ability to operate independently from

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global challenges. Schools must evolve into learning environments that foster environmental awareness while teaching sustainable ethics and developing young people's deep understanding and active participation to build a better future (UNESCO, 2021).

Science education functions as a vital connection between established theories and evolving environmental circumstances. Students develop scientific reasoning abilities alongside critical thinking skills to analyze complex environmental problems through holistic systemic approaches (Alali & Al-Barakat, 2024). Teaching science with an environmental perspective develops learners who not only comprehend ecological systems but also bear the responsibility to engage in their protection and restoration (Castro & Gómez Zermeño, 2020; Li & Shein, 2023).

As noted, the school provides a unique opportunity to mold a generation of active environmental citizens by scientifically teaching and fostering environmental literacy with the use of the integrated curriculum and teaching approaches based on direct learning, observation, community engagement, and project work (UNESCO, 2021). Today's environmental challenges are too urgent to be addressed with outdated educational models. They require a forward-thinking vision that positions science as an analytical, empowering, and action-oriented discipline—and that instills in learners the conviction that they can and must contribute to a more just, resilient, and sustainable world.

Literature Review

As global environmental problems become more intricate, it is crucial to strengthen the relationship between education, especially science education, and instilling environmental consciousness in the youth (UNESCO, 2021). The problems of climate change, pollution, depletion of natural resources, and loss of biodiversity are no longer of scholarly concern; they are now existential dangers to humanity. Such threats require science education not just as an isolated subject in the curriculum, but as part of a holistic, systemic approach to education, starting at an early age (Khasawneh et al., 2023; Li et al., 2019; Pandey et al., 2022).

It is no longer acceptable for science education to depend on explaining natural environmental phenomena and the rote memorization of scientific knowledge. It has become indispensable to adopt current approaches that promote inquiry, critical thinking, and problem-solving, as they empower students in constructing scientific knowledge and prepare them to be active participants in today's innovative and technology-based societies. Contextual-environmental science education raises environmental awareness among students, enables them to realize the relationship between science, environment, and human attitudes, and makes them active participants who can make responsible decisions instead of being passive learners (AlAli & Al-Barakat, 2024; Pandya & Dibner, 2019; Pramling et al., 2024).

The integration of environmental considerations into science education reinforces the skills of critical thinking, collaboration, problem solving, and reasoning, as well as eco-citizenship (Spiteri, 2020; Srisathan et al., 2024; Turrini et al., 2018; Weldemariam et al., 2017; Yıldız et al., 2021). It also supports implementation of active learning techniques that enhance motivation, sustained engagement, and leadership (Srisathan et al., 2024; Yıldız et al., 2021).

Accordingly, schools are important spaces for raising awareness of environmental aspects within students' daily lives. Through experiential learning, students grasp the consequences of human activities, and they are empowered to evaluate and tackle environmental issues constructively and innovatively (Spiteri, 2020; Weldemariam et al., 2017; Yıldız et al., 2021).

This educational model is effective, with a strong emphasis on how thoroughly the teacher is trained. Educators need to specialize in environmental issues and in teaching methods that stimulate ecological reasoning. It has been shown that prepared teachers have a considerable, positive influence on the students' environmental attitudes and behavior by promoting ethical values and systems thinking (Al-Barakat et al., 2025; Elrick-Barr et al., 2023).

Environmental sustainability depends heavily on projects that combine fieldwork with laboratory research and environmental initiatives. The methods enable students to build their scientific inquiry abilities while fostering environmental responsibility and community involvement (Baptista et al., 2025; Castro & Gómez Zermeño, 2020). The process of tracking air quality and finding its sources and creating solutions for environmental issues in local areas helps students develop teamwork abilities, communication skills, and civic engagement (Li & Shein, 2023; Markula & Aksela, 2022).

The implementation of sustainable practices in schools demonstrates system management through their operational and administrative aspects, which support energy preservation and waste reduction, and water management, and promote creative green solutions. The educational method enhances classroom learning because

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it demonstrates how scientific methods create beneficial social transformations (Adamou et al., 2021; Al-Hassan et al., 2012; Eryaşar & Özel, 2025; Fraihat et al., 2022).

Academic researchers now understand that schools function as transformative environments for environmental education. The educational environment serves as a dual-purpose area which delivers content while developing students into environmentally conscious individuals who wish to create positive change in society (Al-Barakat et al., 2025; Khasawneh et al., 2022). According to Al-Barakat et al. (2023), environmental science education requires integrated methods that use scientific analysis to study the complex human-nature connections. This approach enables scientists to expand their knowledge base through environmental problem-solving applications of scientific principles.

Students need to learn how to identify relationships between system components because this skill helps them solve complex environmental issues. Students who learn this way develop enhanced abilities to identify relationships between different elements and understand environmental and political effects of decision-making (Al-Hassan et al., 2025; Bani Irshid et al., 2023; Ebitu et al., 2021; Elrick-Barr et al., 2023; Ernst et al., 2021; Ertz et al., 2016). The students maintain a consistent ability to perform sustainable environmental planning and complete holistic analysis tasks.

Students develop better environmental understanding through direct teaching combined with cooperative and inquiry-based approaches, which also builds their environmental awareness and active participation. Students who participate in waste audits, track energy usage, and develop green projects learn sustainable practices which they apply to their everyday activities (Ernst et al., 2021; Eryaşar & Özel, 2025; Fraihat et al., 2022).

Studies show students who participate actively in environmental education demonstrate better sustainability practice adoption and environmental protection participation (Markula & Aksela, 2022; Mathie & Wals, 2022; Menchaca-Torre et al., 2024; Schutte et al., 2025; Torsdottir et al., 2024). Project-based learning has been found to successfully merge environmental concepts with student values while simultaneously building their critical thinking and creative skills and decision-making abilities (Hadjichambis et al., 2024; Hawamdeh et al., 2025; Hedefalk et al., 2015; Kahriman-Pamuk & Olgan, 2020).

Environmental science learning requires the integration of cognitive understanding with affective understanding to achieve its essential learning outcomes. Students use meaningful engagement with information to transform their understanding into actions which create positive changes in their environment (Li & Shein, 2023; Markula & Aksela, 2022). This raises their feeling of control and connection to their community and, consequently, promotes their environmental stewardship (Baptista et al., 2025; Li & Shein, 2023; Markula & Aksela, 2022; Mathie & Wals, 2022).

Through implementation of transformative science education approaches, students become active environmental citizens who utilize their knowledge to perform ethical environmental teamwork that demonstrates how humans can harmonize with nature to resolve environmental issues (Baptista et al., 2025; Castro & Gómez Zermeño, 2020).

Beyond conventional academic education, environmental science education utilizes multidisciplinary principles that adopt social, ethical, and cultural practices based on knowledge and values to positively influence human-nature relationships. This provides that curricula need to be adjusted, teachers need to be well prepared, and sustainable teaching models and goals need to be set (Mathie & Wals, 2022; Menchaca-Torre et al., 2024; Schutte et al., 2025).

Through combining knowledge, personal values, and complete teaching frameworks, science education can promote environmental awareness among students and raise the level of future pressing environmental challenges evaluation competencies among them.

Research Problem and Significance

Amid the escalating environmental challenges facing the world today, such as climate change, ecosystem degradation, and various forms of pollution, there is an urgent need to prepare a generation with profound environmental awareness and the intellectual and skill-based capacities to address these issues effectively and responsibly, and due to its role in building this awareness, science education is a key tool for instilling environmental concepts and instilling sustainability attitudes.

The reality of education demonstrates obvious shortcomings in the implementation of environmental education effectively, since there is a clear gap between environmental concepts and practices, which can be attributed to conventional teaching methods that restrict the ability to connect knowledge to real life. In this context, Al-Barakat et al., (2025) reported that students' environmental knowledge is marginal and is not strengthened by practices.

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In the Arab context, educational institutions encounter significant challenges in utilizing interactive teaching methods, especially in terms of connecting environmental knowledge to environmental awareness, practices, and citizenship at the primary education level, as available studies focus on knowledge instead of value-based attitudes, which, in turn, is a research gap. Accordingly, this research aimed at exploring science teachers' perceptions of the role of science education in raising students' environmental awareness and shaping their environmental attitudes.

Teachers are the central element linking educational content to classroom reality. Their perceptions directly influence the nature of educational activities and the extent to which environmental issues are integrated into the learning context, which in turn reflects on the level of student awareness and their active engagement in environmental issues.

This research arises from the reality of limited research in the Gulf region addressing science teachers' beliefs regarding Education for Sustainable Development (ESD). Consequently, it contributes to filling a significant research gap by providing insights into the factors that enhance or hinder the integration of sustainability concepts into science education within learning environments characterized by distinct cultural and social specificities. These insights contribute to a better understanding of how to support sustainable education as an approach for shaping conscious and active generations at both the local and global levels.

The significance of this research lies in its ability to provide a deeper understanding of how to utilize science education as a means to encourage critical environmental thinking and build active environmental citizenship from the earliest educational stages. This contributes to preparing a generation capable of confronting environmental challenges responsibly. The research also promotes a shift towards education that stimulates behavioral and value change, moving beyond mere knowledge transfer by linking learning to students' daily environmental reality.

Furthermore, the research's importance extends beyond the Gulf context. Its findings contribute to developing educational models applicable in diverse educational environments, aligning with international efforts to align education with the Sustainable Development Goals (SDGs). Although the research focuses on the Arab Gulf, its dimensions extend to the global context, particularly in environments facing similar cultural or educational challenges. It enriches the discourse on developing curricula and teacher preparation programs that consider the specificities of local contexts without overlooking the universal principles of sustainability.

Based on the above, the research focuses on the following research question: *To what extent does science education in the primary stage shape students' environmental thinking and their behaviors towards sustainability, and develop active environmental citizenship that contributes to building a sustainable and just future?*

Research Methodology

Design

This study adopts a qualitative research design, selected for its effectiveness in examining complex educational phenomena within their natural, real-world contexts. This design is mainly well-suited to investigating context-dependent and value-laden subjects, such as the role of science education in nurturing sustainable environmental behaviors. It focuses on a purposively selected sample of science teachers from three Gulf Cooperation Council (GCC) countries: Saudi Arabia, the United Arab Emirates, and Bahrain. These countries, while culturally and regionally aligned, represent distinct educational systems. Studying them collectively offers a cohesive yet varied regional perspective, enriching our understanding of how environmental sustainability is integrated into science education across different national frameworks.

Data were collected over a seven-month period, from September 5, 2024, to April 28, 2025. This extended duration enabled the researcher to conduct in-depth, semi-structured interviews with participants within their professional environments. The choice of a qualitative approach is rooted in the recognition that teachers' beliefs and individual interpretations significantly influence how students engage with environmental issues. As highlighted by Creswell (2018) and Cohen et al., (2017), qualitative research is particularly suited to exploring the lived experiences and subjective perspectives of individuals. In this context, it allows for a nuanced investigation into how science teachers understand and implement sustainability concepts in their teaching. Additionally, aligning with Oliver's (2016) view, education for sustainability is inherently shaped by its context—social, cultural, and pedagogical. Capturing these dynamics requires a methodological approach capable of revealing layers of meaning that quantitative methods may overlook.

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Sample

The research sample consisted of 51 primary science teachers from private schools across three Gulf Cooperation Council (GCC) countries: the United Arab Emirates, the Kingdom of Saudi Arabia, and the Kingdom of Bahrain. Participants were selected using a purposive convenience sampling method, based on their availability and willingness to participate in in-depth, semi-structured interviews designed to explore their perspectives.

In reference to Cohen et al., (2017) and Roller & Lavrakas (2015), the number of participants was determined based on qualitative research principles of sampling, especially data saturation that was confirmed through data analysis phase due to the frequency of the significant ideas within the extracted analytical categories. Accordingly, this demonstrated the sufficiency of the sample size to achieve the research objectives.

Due to the flexibility in implementing the curricula within private schools and the openness to innovative initiatives, participants were selected from those schools, including 18 teachers from UAE, 20 from Saudi Arabia, and 13 from Bahrain. (68.6%) of the participants were females, which reflects a high level of engagement among females in environmental sustainability related issues. The variance in participants' specialties and backgrounds enriched the collected data with multidisciplinary perspectives.

Ethical Considerations

Ethical standards were considered throughout the research to ensure the research design, participants' rights and privacy, as well as their dignity, interviews, and procedures are compliant with ethical principles. Ethical approval and consent were also obtained, and participants were informed of their right to withdraw without any consequences. Confidentiality was also considered, as participants' identifiable information was replaced by aliases, and access to collected data was exclusive only to researchers.

Instrument

For data collection, semi-structured interviews were conducted. The development of the interviews was based on a comprehensive review of the literature relating to Education for Sustainable Development (ESD), in addition to earlier studies relating to environmental citizenship and the role of science education in instilling awareness and responsible environmental attitudes among students.

The initial draft of the interview consists of six open-ended questions that aimed at exploring teachers' strategies, views, and practices regarding environmental education. The interviews were reviewed by a group of experts in science education, sustainability pedagogy, qualitative research methods, who were asked to give their notes and comments. Following their recommendations, two questions deemed redundant were eliminated along with two other questions that underwent rephrasing for clearer relevance. The final interview protocol contained four essential questions which generated detailed reflective answers:

1. In your view, how can science education contribute to building students' environmental awareness and sense of responsibility?
2. How do you integrate environmental and sustainability issues into your science lessons?
3. What teaching strategies do you find most effective in promoting sustainable thinking and behavior among students?
4. Can you provide examples of classroom practices or projects that have helped your students engage with real-world environmental issues?

To ensure the reliability of the instrument, a pilot interview was conducted with six science teachers not included in the main research sample. The same interviews were repeated after a two-week interval to assess consistency. Additionally, responses were analyzed by two independent coders specializing in qualitative data analysis. Inter-coder agreement was calculated using Cooper's formula, yielding a 100% consistency rate between the two analysts. This indicated high reliability and credibility in the coding process and confirmed the robustness of the instrument in capturing the intended constructs (Burton, 2000; Cohen et al., 2017; Glaser & Strauss, 2017).

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Data Collection and Analysis

Data collection was conducted through semi-structured interviews with combinations of two or more science teachers. These teachers received a detailed brief of the research, including assurances of privacy, ethical confidentiality concerns, and thorough explanations of how their details would not be revealed. Compliance with individual calendars and interviews done with mutual agreement fostered goodwill, which is important for the level of communication needed for the exchange of ideas to be undertaken. Interviews were done at times agreed upon by both parties, which fostered goodwill important for the free and open exchange of ideas. Since the respondents were de-identified and their names replaced with codes, accuracy increased because of their willingness to share opinions without fear of being penalized. Enhancements to accuracy stem from users being allowed to edit documents increases the likelihood of errors being corrected, and the accuracy of errors corrected through transcription increases the accuracy of errors.

The gathered data were analyzed using the Grounded Theory Approach (Glaser & Strauss, 2017; Marshall & Rossman, 2016). This involved a critical reading of all interviews, an initial coding, where textual data were deconstructed and analyzed line by line to identify core concepts, followed by axial coding, which focused on connecting and grouping these concepts into interrelated categories with analytical significance. To ensure the accuracy and reliability of the findings, the research implemented rigorous validation procedures, including independent dual assessment of the data by two specialized researchers, as well as the involvement of two external experts for an independent analytical review. The measurement of inter-rater reliability demonstrated significant consistency in evaluations, thereby reinforcing the credibility of the findings and confirming their methodological robustness.

Research Results

The findings revealed a convergence of views and insights among participants, reflecting an advanced awareness of the role of science education as an effective tool in fostering students' environmental awareness and promoting sustainable behaviors. Seven key themes emerged, representing the dimensions through which science education contributes to environmental thinking and behavior:

- Understanding of the interactive relationship between humans and the environment.
- The teacher as a role model in inculcating environmental values, attitudes, and behaviors.
- Empowering students intellectually to anticipate sustainability challenge.
- Linking science classes with real-world awareness.
- Integrating curricula to embed sustainability concepts across disciplines.
- Constructing environmental knowledge through active learning participation
- Empowering the school to become a supporter of sustainable environmental education.

These themes are presented as follows:

Theme One: Understanding of the interactive relationship between humans and the environment

Analyzing the interview data indicates that 49 out of the 51 teachers (96%) think modern science education is not limited to the teaching of concepts and theories. The gateway serves as an essential tool to study the complex relationship between humans and their environment. The process of understanding human-made problems and human effects on social and natural ecosystems leads to increased awareness. Science education enables teachers to connect academic concepts to students' everyday experiences, which builds their understanding and analytical skills about daily activities. One of them said:

> *"Science extends beyond traditional school subjects because it teaches us about environmental occurrences while teaching us about human influence on nature. Students learn about waste disposal into sewers through water cycle studies which both pollutes oceans and endangers human beings and plants."*

Science education demonstrates its interdisciplinary nature through this powerful example. Students develop interest in their studies by using real-life examples of the water cycle to demonstrate critical thinking skills. A different teacher emphasized climate change discussions during their lesson:

> *"The teacher starts by teaching students about climate change through private car usage and excessive electricity consumption which leads to global warming before showing them sustainable alternatives."*

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Educators must establish learning spaces which foster both critical thinking and meditative reflection instead of basic thinking. The students show a desire to transform negative impacts on the ecosystem. Well-designed science pedagogy possesses the power to transform educational culture, and student lives by developing environmentally aware citizens who understand ecological relationships. Another teacher reiterated this with the following comment:

> *"The lessons incorporate current happenings as well as problems, for example, pollution in our sea. I let students study the reasons and effects of pollution so that they know science relates to their lives."*

This response vividly illustrates the principle of context-based learning, where teaching is grounded in students' tangible environments. Such an approach boosts learners' motivation and encourages them to extend their thinking from abstract concepts to practical solutions. When students see how science helps them understand and address real-world problems, they engage more deeply and develop a keen sense of environmental agency.

Theme Two: The teacher as a role model in inculcating environmental values, attitudes, and behaviors.

The analysis showed that 47 teachers (92%) strongly believed that the role of the science teacher should not be confined to theoretical teaching of environmental concepts. Instead, teachers should embody the environmental values they teach, serving as behavioral role models. This awareness underscores the influential role of modeling in fostering environmental commitment, where the teacher's everyday practices become implicit lessons that shape students' own behaviors. One teacher explained:

> *"I make sure to be a role model in everything I do. For example, I avoid using plastic at school and participate in neighborhood clean-up campaigns. This shows students that what I say isn't just talk—it's a practice I live by."*

This comment expresses the idea that there is a connection between action and communication. A responsible educator integrates practical eco-friendly habits into their professional life, confirming that their actions harmonize with their words. Children who respect their caregivers find environmental care and eco-friendly practices have a meaningful influence. Children dedicate their entire lives to practicing environmentally friendly actions. A teacher revealed to me that we executed a community-based educational project together:

> *"The classroom organized recycling and litter collection drives in our community area and provided students with recycling education. We made awareness campaigns through poster creation that were distributed to schools across the surrounding areas. The students responded positively."*

These examples show that participatory projects hold immense value in developing positive environmental attitudes. The examples demonstrate how action-based service-learning approaches develop social responsibility and civic engagement as well as environmental stewardship among schoolchildren. Through poster-making activities for communication skills integration, students develop leadership abilities to advocate for sustainability while expressing their concerns about important matters. This teacher proposes the following method to enhance environmental issue awareness in school curricula:

> *"I demonstrate to my students the significance of using recycled paper whenever it is feasible. This helps my students comprehend that sustainability efforts have environmental value."*

The everyday implementation of sustainability teaching methods continues through the standard practice of using recycled paper. Students develop an understanding that their small actions make a major influence on biodiversity conservation through purposeful environmental education.

Theme Three: Empowering students intellectually to anticipate sustainability challenge.

Forty-six participants, (90.2%), emphasized that teaching science enables students to develop critical thinking skills that help in making environmental-protective sustainable decisions. This indicates that teachers have a comprehensive foresight vision for the necessity of exceeding traditional learning boundaries to face today's sophisticated challenges. A teacher expressed this approach as follows:

> *"My teaching practices involve prompting students to describe their predictions about Earth's future appearance during the next fifty years based on current events. The open questions lead to closed ones, which help students discover sustainable solutions that incorporate pollution reduction and enhance sustainable practices."*

The quote highlights the focus on motivation together with mental engagement, imagination, and operational scenario modeling for informal design-based learning activities within futurism-centered teaching.

This teaching technique goes beyond fictional narratives because it develops worldwide accountability and individual responsibility together with logical thinking to allow students to make smart decisions while protecting the environment by predicting challenges. Through this approach, teachers and researchers can draft initiative-

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taking documents for environmentally constructive alterations, and governments and businesses sector can support this approach.

Also, another instructor pointed out the changing global circumstances and expressed their concern about instructing students properly when saying:

> *"I believe it's our responsibility as educators to facilitate learners towards a new society which is emerging in practically all areas – environmentally and economically. We should try to prepare them now because these shifts bring more complex problems than those to which we are accustomed. Within an accelerating climate shift along with changes to international markets, what I try to help them is how they can contribute towards adaptation policies, for example, through sustainable energy innovation."*

This answer presents an expanded perspective about the problem. Education reaches beyond closing knowledge gaps to enable students to develop innovative solutions against future economic challenges, environmental disasters, and international geopolitical issues. The educator views his work as more than knowledge transfer because he wants students to become active creators of their reality rather than simple observers. Through the integration of modern technologies, including renewable energy, students learn about scientific solutions and develop their capacity to think about environmental technologies that benefit the planet.

Some educators noted the ethical boundaries of science education because they stated that:

> *"Science education should develop future scientists who learn about ethics and future impacts. The ideal educational process should develop students who remember specific facts as they contemplate the consequences their actions have on nature. The goal should be to develop students who understand the environment along with the rights of future generations."*

The scientific concept integrates with the emotional aspects of science learning, according to the teacher. A student must comprehend laws and theories alongside developing ethical understanding to evaluate the environmental impacts of their decisions for becoming a morally responsible scientific thinker. The scientific terms emissions and consumption and global warming become personal values which direct students toward sustainable behavior.

The information provided indicates the ways Science teachers attempt to shape students' vision towards the future using their understanding of the environment, predictive reasoning, and responsible actions. From this data, it can be observed that the construction of Science Education evolves into a process of helping the students to become future creators, instead of passive victims of environmental degradation, through critical anticipatory thinking.

Theme Four: Linking science classes with real-world awareness.

The data revealed that 88.2% of the 51 teachers (45 out of 51) demonstrated their dedication to linking scientific content to students' local environmental contexts. The method seeks to enhance learning relevance and emotional engagement through the use of students' everyday experiences. These practices demonstrate the implementation of contextual learning strategies, which research effectively connects science education to community involvement. One teacher explained:

> *"In our village, people struggle with water scarcity. So, when I teach the topic of water scarcity, I begin with the situation in the village where most students live. I explain how the lack of water affects farming and daily life. From there, we discuss local water sources and ways to reduce waste."*

This example illustrates how leveraging the local context can make environmental education more tangible and meaningful. Beginning with a problem familiar to the students gives the lesson greater personal relevance and motivates learners to understand and contribute to real solutions. Context-based learning enhances students' sense of social responsibility and reinforces education as a tool for both social and environmental change.

These findings also show that this category of responses reflects an intentional effort to embed scientific content within the student's lived environment—starting from a real problem the local community face. When problem-solving is grounded in topics that students perceive firsthand, it fosters internal motivation and strengthens the connection they feel toward their environment and the responsibilities within it. An additional comment from another educator was:

> *"Every region has its own environmental problems. We need specific contextual environmental education relevant to a local framework. A green region cannot be taught about desertification, just like a manufacturing city cannot have industrial pollution ignored. There should be adaptable teaching plans and curricula tailored to each area's special concerns."*

The quotation illustrates insightful understanding of how curricula require modification. Teaching should be meaningful for a particular context, and in the case of science, it must take into account the region's environmental issues. Science classes tailored to local challenges build students' critical thinking skills and their ability to practi-

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cally solve problems. These responses reflect the need for flexible, adjustable curricula that foster active learning with community relevance as well as student participation through direct relationships between learning materials and the outside world.

Another illustrative practical example provided by one of the teachers that strengthens this argument is:

> *"In my assigning interactive city pollution hotspot maps construction to my students, they were able to identify important pollution areas on the map. Subsequently, we conducted a brainstorming session about how pollution can be reduced. They all showed deep sense of responsibility towards their own community."*

This exemplifies an integration of service learning and science teaching. Concepts such as pollution are addressed beyond theoretical analysis through applied environmental stewardship: they are mapped out, and solutions are proposed. Learners actively engage with issues through mapping, encouraging collaborative problem solving while fostering innovation. The follow-up discussions reinforce group identity while cultivating unity toward taking care of their environment, which extends into participatory citizenry within their community.

Theme Five: Integrating curricula to embed sustainability concepts across disciplines.

The survey findings show that 43 out of 51 teachers (84.3%) agree that science teachers should not bear the sole responsibility for sustainability promotion. The development of sustainability needs ongoing collective efforts from various stakeholders who share a unified institutional vision. The participants emphasize that sustainability education through interdisciplinary approaches extends beyond environmental education because it includes cultural and ethical aspects. The participant explained that:

> *"At the school, you as science teacher can't instill a culture of sustainability by yourself. Sustainability culture requires collaboration with social studies and language teachers. These are all the subjects' children learn about sustainably—the concepts are woven everywhere."*

The teacher described how their school used an integrative framework to develop a specific collaborative project.

> *"The students learned about tree deforestation through two connected stories which I taught them about greed leading to deforestation and my Arabic language colleague presented to them. The students developed complete understanding of their plant conservation lessons because they became deeply invested in the story's emotional content."*

Another adjunct role provided with social studies, history, or geography classes stated:

> *"This infective way; climate change or desertification becomes so tightly coupled with everything else that we teach! And this creates great engagement for students from environmental science with sociopolitical issues."*

The cases demonstrate that we require flexible thinking between subjects, which enables students to learn beyond single subjects. The instructors found that sustainability education with cultural integration needed traditional methods to teach across different teaching approaches. Students learn scientific concepts through stories and literary works, including novels and poems, which helps them understand science through imagination and emotions while moving past memorization.

The data provided an example of an institutional governance framework exemplifying an interdisciplinary approach. One of the participating teachers commented on this school initiative:

> *"Our school undertakes an initiative called 'Green School.' It integrates all subjects. For example, math classes calculate water and energy usage, art creates awareness posters, Islamic education talks about humanity's responsibility towards nature, and science tackles local ecological problems."*

Another teacher said:

> *"Every single event at the school has an environmental theme. For example, nature is celebrated through art where students create art during art classes, sustainability are addressed during essay competitions in the language classes, and recycling is played during PE in the form of games."*

These instances show there is some progress from individually motivated environmental education toward a more holistic, institutional framework anchored in interdisciplinary collaboration. When the assimilation of the concepts of sustainability permeates all teaching and daily practices within the life of the school, the school can be considered an educational ecosystem embodying living for the environment. An education based on sustainability creates an extensive framework which connects all aspects of the educational process. Education integrates critical collaboration with problem solving while adopting an interdisciplinary method to tackle complex sustainable challenges that need critical thinking.

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Multiple educators concluded that sustainability teaching should not operate independently. One participant beautifully articulated this as follows:

> *"The practice of sustainability in students encompasses waste management, electricity consumption, essay composition, and project topic selection. The child learns sustainability through all academic subjects rather than focusing on one particular subject."*

The school needs to function as a unified system where educational responsibilities merge with ethical and emotional responsibilities to achieve holistic and harmonious integration of every sustainability aspect within teaching frameworks. The integration of theoretical knowledge with practical skills allows students to fully internalize sustainability principles throughout their educational foundation.

Some educational institutions advanced their sustainability education through cross-disciplinary extracurricular activities. One of the teachers shared:

> *"The annual environmental exhibition serves as an example of our inter-departmental program. Students who study language create environmental speeches and poems. The math department uses numbers to present consumption data. Science students conduct recycling experiments while art students create environmental posters. Multiple teams working together prove that different approaches can unite to achieve one common objective."*

Sustainability serves as a value which schools can practice in their daily operations. A collaborative education model emerges through interdisciplinary approaches, which transforms the school into a small-scale sustainable community. Students develop both environmental knowledge and appropriate attitudes through various experiential learning activities that span across multiple disciplines. Education shifts from information delivery to the promotion of sustainable development practices both inside and outside the classroom.

Theme Six: Constructing environmental knowledge through active learning participation.

From the data collected, it was clear that 94.1% of the respondents were trying to transform the student's role from that of a knowledge consumer to an active producer of environmental knowledge. This is achieved through modern learning techniques such as research-based learning, observation, experimentation, class discussions, and group projects. This indicates a shift towards a constructivist model, where the prevailing philosophies are beginning to embrace students as collaborators in the knowledge construction process, rather than as passive vessels to be filled. The teacher's paradigm of learning and teaching is being supplanted by an environmental education paradigm, which emphasizes active learning and the application of knowledge in real-world contexts beyond the four walls of the classroom. One teacher shared this classroom practice:

> *"I ask students to find solutions for their neighborhood garbage problem and report back in class. Some designed waste-sorting bins; others wrote proposals for the municipality. More creative than responsible really but either way they were producing innovative ideas."*

Through the project-based learning paradigm, learners are empowered to address real-world environmental challenges within their communities, which enhances their critical and analytical thinking, as well as civic engagement. These approaches empower students to engage in environmental issues as they learn about ecological citizenship and community responsibility, which are core tenets of sustainability education. The strategies are more than projects as they include observation and experimentation in the real world. For example:

> *"For our unit on Insects, I included the observation of some insect species as well as the study of the power of some pesticides in our school garden."*

Another participant stated:

> *"Students looking for insect species around the school and us evaluating the influence of pesticides, for instance, are moments that I remember vividly. They brought so much life to learning."*

Through these types of inquiry-based learning, "junior researchers" can engage with different environmental issues, evaluate the roles, and develop scientific skills including observation, measurement, and interpretation. Such actions improve one's reasoning about cause and effect as well as individual responsibility for environmental issues. A teacher recalls marking what many consider the most astonishing insights:

> *"Classroom debate about the environment as a theme often suggests solutions well outside the scope of what I or any adult could imagine. They were and still a source of wonder, but also a comfort in the belief that our children can reason."*

Technology as a lesson aid has changed from a tool of one-way data transmission to the students, leaving them as a vessel to be filled, to a paradigm where instructors are on the other side of the fence, learners are the

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ones equipped to sculpt knowledge through advanced questions, puzzles, and even, informal hints. Instead of blindly waiting for information to be offered to students in an overly structured setting, learners in the modern world actively engage with the information concept through technology and the internet.

There are countless other factors that strive to assist motivation and mindset towards self-supported inquiry. Understanding basic facts in a science class and even advanced knowledge on combatting certain environmental issues through the relevant skill sets allows students to actively engage as citizens and volunteers. The ability to think moves far beyond the facts presented in science lessons.

This shift demonstrates how beneficial motivation is to the freedom of learners. Environmental education should not be purely for the sake of gathering information, but instead, should work to raise awareness and inspire initiative-taking, transformative action towards working for a sustainable future. This brings to life the idea of a modern school which aims to cultivate educated, engaged, and socially responsible citizens actively working towards improving the conditions of their world.

Theme Seven: Empowering the school to become a supporter of sustainable environmental education.

44 out of 51 teachers (86.3%) emphasized that the success of environmental education depends not only on classroom teaching, but significantly on how well the school environment, as an educational institution, supports environmental values and behaviors. Teachers noted that schools effectively promoting sustainability are those that embody these values through daily practices, environmentally conscious management, eco-friendly facilities, and institutional behaviors that align words with actions. As one teacher put it:

"If a school doesn't separate its waste, how can it ask students to respect the environment?"

Another added:

"How can we ask students to care about the environment if the school wastes resources? The school should be a role model."

These statements highlight the critical role of institutional modeling. Students learn more from lived examples than from verbal teaching. A disconnect between what is taught and what is practiced undermines credibility and diminishes students' motivation to adopt sustainable behaviors—especially when the institution itself fails to uphold the values it promotes.

Therefore, schools should not merely include sustainability in curricula but must practice it through everyday institutional behavior—such as waste separation, energy conservation, water efficiency, and use of recyclable materials. These actions provide students with a living example that sustainability is not just a slogan, but a practical, cultural, and institutional reality embedded in their learning environment.

A number of participants highlighted the importance of providing spaces to demonstrate students' environmental achievements. As one teacher recalled:

"We put up a school corner for over environmental projects and it sparked interest and healthy competition."

Another participant added:

"Prominently displaying student work not only drew excitement but also pride in putting the environment first."

The school climate becomes more motivational through these initiatives because they recognize student initiatives and celebrate them, which leads to higher student engagement and ownership. The display of environmental work establishes open dialogue spaces which enable peer learning and collective awareness to inspire students to challenge each other toward more active environmental roles.

Facilities and Physical infrastructure were listed under environmental education. One teacher noted:

"Even the school's layout and its natural lighting, ventilation have to comply with environmental standards. It is part of silent education."

This response indicates that the facilities are not only a place where learners skull exercises by practicing their literary skills but also valued within the structure whose hierarchical system comprises pedagogical incentives. Space itself supports the development of conservation awareness. Students practice stewardship because of the school's structural features like windows. They are placed strategically to allow for maximum sunlight to reduce electricity use, and natural methods are employed to ventilate air, thus minimizing the need for air conditioning. Thus, the green building design used by the school goes beyond providing healthy indoor environments-eco

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conscious construction provides non-verbal teaching. It silently instructs learners on respecting environmental practices in all life facets, including construction and physical structures.

Discussion

Science educators have dedicated their efforts toward integrating sustainable environmental mindsets within their educational approaches. Participants showed readiness to integrate suitable science content at educational levels for developing environmental protection attitudes. The prevailing attitude among the participants suggests that climate change, pollution, and destruction of ecosystems need to be addressed in education as ethical challenges that demand holistic pedagogical approaches. The debates about the policy frameworks of education in relation to the international plans regarding Education for Sustainable Development (ESD) vis-a-vis the UAE and Saudi Arabia prompted this focus (AlAli et al., 2024).

Teaching, as a profession, includes awareness as the unifying thread of the pedagogical and professional responsibilities of teachers, which in this case, is the modern environmental approaches and theories (Al-Barakat et al., 2023). The existing research literature (Hadjichambis et al., 2024; Hawamdeh et al., 2025; Khasawneh et al., 2023; Pandya & Dibner, 2019) is in support of this concept and recommends document analysis of the curriculum concerning the pedagogy of sustainability science. AlAli and Al-Barakat (2024) articulated the urgent need to design in-service programs for teachers to impart these values.

The research shows that teachers now move away from conventional lectures to implement interactive methods which help students connect with environmental matters. The study discovered that discussion, along with inquiry and critical reflection, served as the primary teaching strategy to transform educational practices from memorization-based learning into active discovery-based learning. The understanding of teachers' roles has shifted since they now function as facilitators of learning rather than providers of authoritative information. This learning approach follows John Dewey's constructivist theory, which demonstrates that individual experiences generate the best learning outcomes, and education should relate to students' everyday experiences. This also supports Hadjichambi et al.'s (2023) findings regarding the effectiveness of teaching environmental issues on students' critical thinking skills.

The research also focused on the emotional and behavioral aspects of environmental education, describing how participants noted that environmental values are taught through both content and through the teaching staff's habits and actions during work hours on and off school grounds. This demonstrates a belief that the teacher's context is vital to effective environmental education, in which the teacher is expected to practice what he or she wishes to teach. The participants demonstrated their commitment to environmental practices by implementing three main strategies that included paper reduction in classrooms, recycling programs, and energy conservation measures. The findings support Bandura's social cognitive theory regarding observational learning because the teacher serves as a model for the students to imitate. The findings align with previous research (Eryaşar & Özel, 2025; Ernst et al., 2021; Hedefalk et al., 2015; Kahriman-Pamuk & Olgan, 2020; Kahriman-Pamuk et al., 2022), which demonstrates how teachers' actions align with eco-friendly principles to produce authentic and impactful learning experiences.

The findings demonstrated that the participants realized that emotions could shape environmental attitudes among students with almost equal attention levels, since they utilized reflective work, field-based activities, and nature-based sensory experiences to build relationships between students and the environment. Here, environmental education shifts from cognitive-oriented model towards a comprehensive framework that, in line with humanistic theory, aims at building continuing positive environmental behaviors. Modern educational approaches emphasize that environmental education succeeds through affective learning that enables students to develop environment-emotional relationships that lead to responsible behaviors. Research (Elrick-Barr et al., 2023; Ertz et al., 2016; Fraihat et al., 2022; Ghosh & Prasad, 2024; Hadjichambi et al., 2023) reported that students developed positive environmental attitudes through interactive environmental activities.

Also, the findings revealed that participants achieve the goals of environmental learning through merging multiple subjects together and have built interdisciplinary connections to present environmental sustainability concepts through integrated curricula that provide better comprehension of environmental education as an interconnected system that requires school community participation. This teaching strategy, which is consistent with Multidimensional Learning Theory, contributes to developing curricula through improving students' comprehension of sophisticated environmental issues. The integration of curricula has been proven to establish connections between scientific knowledge and environmental contexts according to Al-Hassan et al. (2025).

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Environmental education moves away from traditional information reception when students engage in project-based learning as they become active creators of knowledge and solution developers. This method relies on student-led environmental projects in which students practice some activities that help in managing local environmental issues, which result in developing community-oriented competencies through merging academic knowledge with real problems. This empowering method supports the UNESCO document as well as Al-Barakat et al., (2025), as both claimed that active learning contributes to raising environmental awareness among students.

Research findings emphasized the important role of learning environment such as organizational structures, administrative practices, and facilities in teaching environmental values, which is consistent with the ecological learning theory that highlights the role of the entire educational environment in developing sustainable environmental attitudes through combining physical environment with environmental activities and practices, such as waste recycling programs and renewable energy system. Al-Hassan et al., (2025) reported that proper school environment supports environmental education success through enabling students to transform learning into lasting attitudes.

Conclusions, Recommendations, Limitations, and Future Research Directions

Modern educational literature underscores a significant gap in comprehending the genuine potential of science education to shape students' environmental awareness and equip them to become responsible, active global citizens engaged with issues of environmental sustainability. While prior research has often examined science education through the lenses of content and methodology, few studies have undertaken a deep examination of its contribution to fostering sustainability thinking in learners, specifically in connecting scientific concepts to their daily behaviors, values, and environmental attitudes. It is from this identified gap that the present research derives its importance, seeking to provide a conceptual and applied framework for reconceptualizing science education as a strategic tool that actively supports sustainable development within the school environment.

Research findings emphasize the need for high-quality training programs with which teachers can effectively connect scientific concepts to students' entire environmental context, since this approach develops critical thinking among students and enables them to make ethical decisions based on their scientific and environmental understanding. The role of science teaching must go beyond knowledge transfer to empowering students in understanding today's environmental challenges and participating actively in resolving them. This, in turn, makes it necessary to shift the students from passive knowledge recipients to active participants in knowledge construction.

Besides, the research findings identified seven essential dimensions in science education for sustainability: understanding the interactive human-environment relationship, the teacher as a role model for positive environmental values, empowering students to anticipate future environmental challenges, linking lesson content to local contexts, integrating sustainability across disciplines, motivating students to become producers of environmental knowledge, and establishing the school as an institutionally supportive environment for sustainable practices. This highlights the role of the school as a complete environmental system that must demonstrate a commitment to sustainability principles through tangible policies and practices that confirms the alignment between theory (curricula) and practice.

Therefore, the research recommends revising teacher preparation programs and developing policies that support teachers' ongoing professional development which, in turn, enable them to connect theory to practice. It also recommends developing the curricula to embed sustainability as a central pillar of educational identity, as well as school culture and practices.

There are several limitations that constrain the generalizability of the research findings to broader educational contexts; the sample was restricted to science teachers within private schools across three countries in the Gulf area. In addition, using only semi-structured interviews is a methodological constraint that may lead to social desirability bias, in which participants do not reflect actual practices but express ideal attitudes.

Towards developing effective educational models that resonate with the realities and growing environmental needs of Arab societies, future research needs to be expanded to include teachers from both public and private schools, study different learning environments, and adopt multi-method methodologies that combine interviews, observations, and educational document analysis, which may provide actual classroom practices. Moreover, an in-depth analysis of curricula content is crucial, and policy makers are required to examine the extent to which environmental values and sustainability concepts are embedded in educational practices.

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The authors declare no competing interest.

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